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OBSERVATION D'UN VOL EN ESSAIM D'*AIOLOPUS THALASSINUS* (FAB.) (ORTHOPTÈRES-ACRIDIDAE)

Par Ch. Rungs.

(*Rabat, Maroc.*)

Communicated by Dr. B. P. Uvarov, F.R.E.S.

A Rabat (Maroc), le 12 juillet 1938 à 21 h. 15 (heure locale), par une température de 20° C. et une humidité relative de l'air voisine de la saturation en vapeur d'eau, un essaim peu compact d'Acrididae appartenant à l'espèce *Aiolopus thalassinus* (Fab.), tourbillonnait sur la colline qui borde vers l'ouest les marais-salants, le long de l'Oued Bou Regreg. Une centaine de ces insectes vinrent se poser sur le balcon de mon appartement où était allumée une lampe électrique. Intrigué par cette pullulation d'Orthoptères, je suis allé dans la rue et j'ai vu d'assez nombreuses sauterelles tourbillonner autour des réverbères électriques. En outre, en regardant dans la direction de la lune, il était possible de distinguer des Acridiens volant en tous sens, grâce au miroitement de leurs ailes sous les rayons lunaires. J'évalue le nombre d'*Aiolopus*, qui volaient ce soir là, à plusieurs centaines et peut être même à plus d'un millier. Les insectes étaient extrêmement vifs si bien que je n'ai pu capturer que 15 mâles et 9 femelles. Tous les individus pris étaient de coloration brune, sans aucune trace de la teinte verte, pourtant normale chez cette espèce.

Les 13 et 14 juillet au soir, quelques spécimens vinrent encore à la lumière : ils étaient également de coloration brune; mais je n'ai pas constaté de vols en essaim.

Le 12 juillet, deux individus de *Acrotylus patruelis* H.-S. ont été capturés dans l'essaim venu se poser autour de ma lampe.

Etonné par ce vol massif d'une espèce réputée plutôt sédentaire, j'ai demandé à M. B. P. Uvarov, de l'Imperial Institute of Entomology, à Londres, si le fait était intéressant. Avec son amabilité coutumière, cet eminent spécialiste, dans sa réponse, m'a invité à faire connaître ces modestes observations en me posant un petit questionnaire auquel je réponds ici dans la mesure où je puis être affirmatif :

1°. " How long did the flight last? "—

Je puis dire que jusque vers 22 h. 30 les arrivées d'Orthoptères à la lampe et leurs départs ne cessèrent pas; vers 23 h. le vol en masse semblait terminé et les *Aiolopus* étaient posés un peu partout, isolément, dans la rue, les jardins voisins et le terrain vague situé en face de mon domicile.

2°. " The maximum temperature during the day preceding the flight. (It would be interesting to compare this with the maximum temperatures during the previous days.) "

Je donne ci-dessous le relevé de la Station météorologique la plus rapprochée du lieu de l'observation : elle est située à environ un kilomètre à vol d'oiseau, à une altitude de 63 mètres, alors que les marais-salants de Rabat, en bordure de l'Oued Bou Regreg, et où vivent normalement les *Aiolopus*, sont a peu près au niveau de la mer.

Il est certain que l'on constate un accroissement progressif du maximum de la température du 8 au 12 juillet; mais je ne crois pas que l'on doive voir là, la cause du vol. Bien souvent à Rabat, en effet, la température maxima de la journée est supérieure à 27° C. et dépasse même 30° C. sans que l'on observe de tels vols d'*Aiolopus*. Je puis être affirmatif, car depuis trois ans ma lampe fonctionne toutes les nuits en vue de la capture des Lépidoptères et jamais je n'ai vu venir des masses d'Acridiens. Quelques isolés sont cependant attirés de temps à autres par mes lumières (*Aiolopus thalassinus* (Fab.), *Euprepocnemis plorans* Charp., *Locusta migratoria* L. ph. *solitaria*, *Acrotylus patruelis* H.-S. ainsi que quelques Blattidae et Gryllidae.

Jours Juillet 1938	Température ° C.		Hygrométrie %	
	Maximum	Minimum	à H. 07·00	à H. 13·00
8	25	18	80	50
9	26	19	90	60
10	26	15	90	60
11	26	16	90	60
12	27	17	80	60

3°. " As far as I know this species lives mainly in oases and oueds, usually in grass not far from water, and it may be suggested that the migration may start because of the drying up of the grass."

Il est exact que l'espèce est abondante dans les marais-salants de Rabat, milieu particulièrement humide.

La végétation de ces marais * est constituée principalement par des espèces ligneuses halophiles telles que *Arthrocnemon macrostachium* Mor., *Salicornia sarmentosa* Duv. J., *Atriplex portulacoïdes* L., *Suaeda maritima* Dum., *Suaeda fruticosa* L., *Inula crithmoïdes* L., *Limionastrum monopetalum* Boiss., *Statice ovalifolia* Poir. Sur les parties où la vase est consolidée, pullule, de novembre à juin, une végétation abondante de nombreuses plantes annuelles banales. Il est certain qu'à la date du 12 juillet, la végétation annuelle était complètement déssechée et que seules restaient vertes et succulentes, les plantes ligneuses énumérées ci-dessus ainsi que quelques Graminées vivaces,* malheureusement très broutées par le bétail.

Il est donc possible que le vol d'*Aiolopus thalassinus* du 12 juillet soit dû à une migration de ces Orthoptères en quête de plantes annuelles vertes.

Il ne s'agit évidemment là que d'une simple hypothèse car il n'est pas du tout prouvé que l'espèce dont il s'agit ne puisse se nourrir du feuillage des plantes ligneuses qui croissent dans la zone de son habitat normal. Il est vrai que le suc de ces végétaux contient une assez forte proportion de chlorures ; peut être ceux-ci agissent-ils comme répulsif à l'égard des *Aiolopus* ?

Resumé.

1°. Un vol en essaim tourbillonnant, de plusieurs centaines d'individus appartenant à l'espèce *Aiolopus thalassinus* (Fab.) a été observé à Rabat (Maroc) le 12 juillet 1938 de 21 h. 15 à 23 h. environ. Léger clair de lune ; température de l'air : 20° C. ; humidité relative voisine de la saturation.

2°. Les insectes capturés dans ces essaims étaient tous de coloration brune et ne présentaient pas de couleur verte, couleur pourtant normale chez cette espèce.

3°. Il ne semble pas qu'un accroissement progressif de la température de l'air pendant les jours précédant le vol soit à l'origine de cette migration.

4°. Il est possible que la recherche de plantes vertes annuelles, alors desséchées dans la zone d'habitat normal de l'espèce, soit la cause de ce départ en masse d'*Aiolopus thalassinus* (Fab.).

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* Cf. L. Emberger et P. R. Régnier : Aperçu sur la végétation de l'embouchure du Bou Regreg. 1926, *Bull. Soc. Sci. Nat. Maroc* **6** : 78–86, 2 pls.

THE EVAGINATION OF THE HEAD IN THE PUPAE OF CYCLORRHAPHOUS FLIES (DIPTERA)

By Gottfried Fraenkel.

Communicated by Dr. O. W. Richards, F.R.E.S.

The cyclorrhaphous flies reach a stage (A) in the pupal development, illustrated in fig. 1, in which the wings and legs are already well formed and have grown about half-way down the length of the body. The head is not yet visible, but is already formed inside the thorax in an invaginated state. In

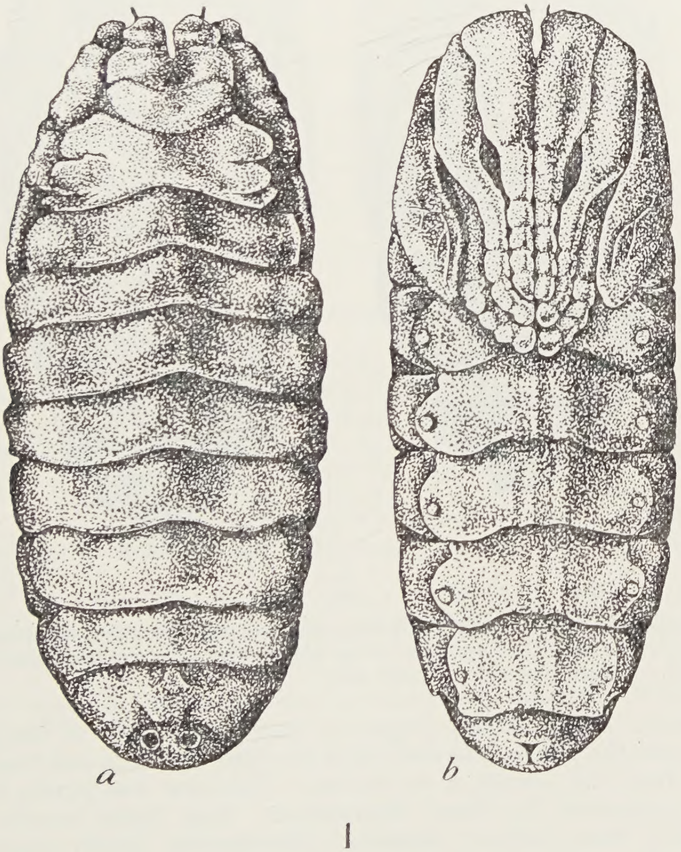

Fig. 1.—Pupa of *Calliphora erythrocephala*, dissected out from the puparium about 30 hours (27° C.) after the formation of the white pupa, shortly before the evagination of the head takes place. a, dorsal view; b, ventral view.

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the next stage (B), illustrated in fig. 2, the head is clearly formed and the legs reach backwards over the whole length of the abdomen. The remarkable point in this transformation is that there is no transitional stage between these two, although they are so conspicuously different in shape. If one open a great number of pupae of *Calliphora erythrocephala* Mg. of identical age and kept at 27° C. for about 30 hours after the formation of the white pupa, they are found in one or other of the two stages. This was known to several of the earlier workers who studied the pupal development of flies, and has given rise to considerable speculation as to the mechanism of head-formation.

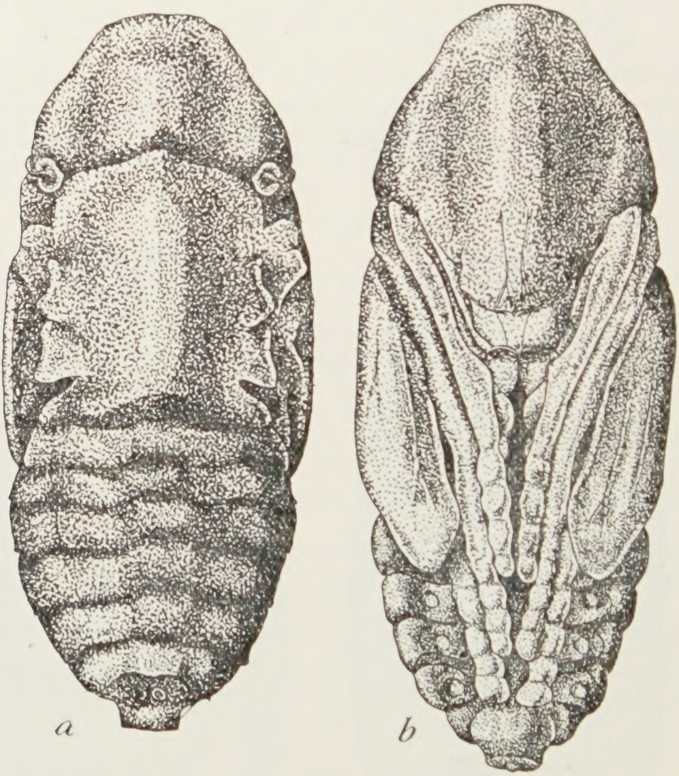

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FIG. 2.—Pupa of *Calliphora erythrocephala*, dissected out from the puparium about 35 hours (27° C.) after the formation of the white pupa, after the head has become evaginated. a, dorsal view; b, ventral view.

Weismann (1864) already suggested that contractions of the abdominal muscles press the partly fluid content of the body forwards and thus force the head out from the interior of the thorax. This view was purely speculative and not supported by direct observations. Rees (1889) merely mentions Weismann's views without comment. Kowalewsky (1885) described slow body movements in the pupa at a time when the head is already visible. This statement is contradicted by Lowne (1890), who states that at the period in question all the body muscles have already degenerated. He ascribed the forces by which the head is evaginated to " organic changes which take place in the cells of the paraderm." " These are slow and continuous." (Lowne's term paraderm for the skin of the early fly pupa has not been accepted subsequently). Wahl (1915), in *Eristalis*, suggested that the transition of the one stage into the other might occur very quickly, possibly within a few minutes.

If the stage A be dissected out from the puparium cautiously, a slight continuous pressure applied to the abdomen is sufficient to evaginate the head to its full extent. During this process body fluid is not only shifted forwards into the head, but also into the wings and legs. The abdomen shortens and the wings and legs lengthen so that the latter reach backwards up to the tip of the abdomen. This artificial transformation of stage A into stage B is completed within a second or less.

If one dissects out from the puparium a pupa of stage A and leaves it quiet it shows very often slow body movements of a peculiar type. A contraction starts in the last abdominal segment and passes as a slow peristaltic wave forwards. It may take five seconds to pass from one segment to the following, and thirty seconds to reach the first abdominal segment, after which a new contraction starts at the end. These contractions become more and more vigorous, and finally the head is evaginated in the course of one of these peristaltic contractions. I have been successful in filming* both the forcible evagination of the head by pressure applied to the abdomen and the natural evagination by peristaltic contractions.

Contrary to Lowne's statement, mentioned above, the muscles of the body wall of the larva persist in the pupa in the same arrangement up to the time when the head is evaginated, and degenerate later. They respond to mechanical and electrical stimuli and retain their normal functions, as is shown by the processes which cause the evagination of the head.

I am much indebted to Mr. H. Hurst for drawing the figures illustrating this paper.

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* Contained in the film, The Blowfly, Gaumont-British-Instructional, Film House, Wardour Street, London, W.1.

Book Notice.

Insects of Citrus and other subtropical fruits. By H. J. Quayle. pp. xi + 583, 377 figs. 8vo. Ithaca, New York. (Comstock Publishing Co., Inc.) 1938. Price $5.00.

This book is written by the Professor of Entomology at the University of Cornell, who is in charge of the University Citrus Experiment Station, and deals with insects noxious to citrus, and a small number of other subtropical fruits such as almond, pecan, fig, and olive, wherever these crops may be grown. The book is not restricted to citrus in America. Chapter I is devoted to the lists of fruits and the insects, including mites, that attack the fruits. A key is given to assist in the identification of citrus insects and mites in the United States of America.

Chapters II–VI deal with the insects attacking citrus, with information on means and methods of control.

Chapters VII–XIV give similar information on insects attacking respectively avocado, vinifera grape, persian walnut, almond, pecan, fig, olive, date and some minor crops. Chapter XV is concerned with pests other than insects and Chapters XVI and XVII with fumigation and spraying and dusting.

In Chapter XVIII is given extracts of the quarantine orders of the various states in the U.S.A.

An extensive index completes the book.

Book Notice.

Problems of animal ecology. By Prof. F. S. Bodenheimer. 8vo. London (Oxford University Press). pp. viii + 184, 28 figs. Price 12*s*. 6*d*.

This work comprises six chapters.

I. Physiological and ecological life-tables and connected problems.
II. The life-history and its ecological interpretation to-day.
III. What really does occur in the *Drosophila* bottle? A further approach to a complete population analysis.
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The book deals with the effects of temperature on development, the length of life of animals in different conditions, age distribution of populations and the methods of studying it, fluctuations in populations, distribution of animal communities in different habitats, and the relation of ecology to problems of heredity and the origin of species.

A list of literature referred to is given at the end of the book arranged in the order in which the references are made in the text and divided into chapters.

This is followed by a page of " notes " and a short index " restricted to topical references."

LIFE HISTORIES OF SOME BUTTERFLIES IN THE NORTHERN TERRITORIES, GOLD COAST (LEPID.)

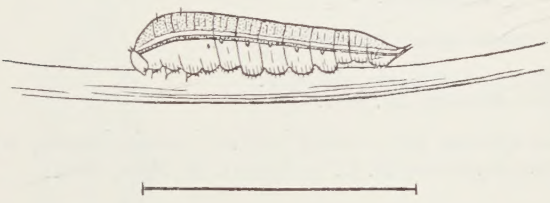
By D. W. Seth-Smith, M.R.C.S., L.R.C.P.

(Edited by G. Talbot, F.R.E.S.)

Foreword by Professor Hale Carpenter.

Some years ago Dr. Seth-Smith very kindly deposited in the Hope Department of Entomology, Oxford University Museum, a number of butterflies bred by himself in the Northern Territories, Gold Coast, together with notes on life histories, pencil drawings, and specimens of the food-plants.

These remained in the care of Sir Edward Poulton, F.R.S., then Hope Professor, who, after devoting a considerable amount of attention to the notes, found himself unable to spare the time required to revise the MS. and drawings for publication. In 1937 I approached Mr. G. Talbot, who kindly undertook to complete the work which Sir Edward had commenced. The pencil drawings being very small were unsuitable for reproduction, and Miss D. Fitchew agreed to make new drawings from the spirit specimens and Dr. Seth-Smith's sketches.



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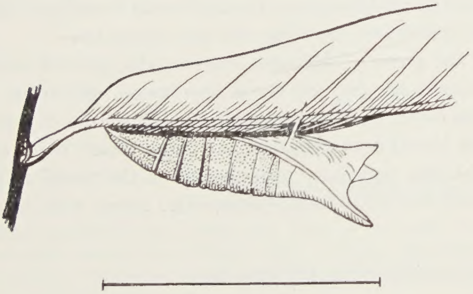

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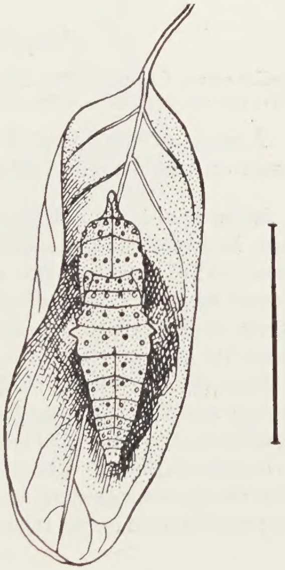

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Papilionidae.

Papilio pylades pylades Fabr. (figs. 1, 1a).

Papilio pylades Fabricius, 1793, *Ent. Syst.* **3** (1) : 34.
Papilio pylades pylades Aurivillius, 1908, *in* Seitz, *Macrolep.* **13** : 21, t. 7c.
Papilio pylades Fleury, 1926, *Ann. Soc. ent. Fr.* **95** : 136 (larva and pupa).

Egg.—Spherical; green, with a pearly lustre. Laid singly on the upperside of the leaves of *Anona senegalensis* Pers., the Custard Apple.

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Larva (fig. 1).—Green, with a lateral tri-coloured band which extends the whole length of the body. The lower third of this band, lying along the spiracular line, is dark green, the middle third white, the upper third yellow. The spiracles are blue. Terminal segment bifid, each fork edged with yellow. Dorsal surface of each segment, except the terminal one and the head, with two transverse purple lines. Prothoracic segment with a pair of short, blunt, black spines, and meso- and metathoracic segments each with a pair of large black spines; the base of all these spines is orange. The larva rests along the midrib on the upper surface of the leaf.

Pupa (fig. 1a).—Agrees with the description for this group of *Papilio* given by Aurivillius, 1908. Green, with two narrow, white, paradorsal lines which coalesce on the metathorax and continue as a single line on to the mesothoracic projection. Two raised, more thickened, lateral white lines, which edge the wing-cases, also converge towards the mesothoracic projection and unite at its apex. Head bifid. The appearance is extremely leaf-like.

The butterfly is common in the Northern Territories of the Gold Coast, being apparently commonest during the dry season.

PIERIDAE.

Anapheis creona creona (Cram.) (fig. 2).

Papilio creona Cramer, 1776, *Pap. Exot.* **1** : 148, pl. xcv, figs. C, F.
Pieris creona Aurivillius, 1910, *in* Seitz, *Macrolep.* **13** : 40, t. 13*b*.

A mass of the larva of this species, each under half an inch in length, was found on two leaves of *Maerua angolensis* D. C. at Lawra, in May, 1931.

Larva, final instar.—Head black above and green below, fairly densely covered with white hairs and white tubercles. Body pubescent above, but with longer white hairs below level of spiracles; fine white dots are sprinkled over the whole surface. Each abdominal segment bears four yellow dots disposed in a transverse ring, and each thoracic segment six such dots. The thin mid-dorsal line is blue-green, the subdorsal broad and light green; the sides are dark green with a pale green line including the grey spiracles.

Pupa (fig. 2).—Shape identical with the pupa of *Belenois subeida*, the ground-colour varying according to surroundings. I had both grey or green specimens, according as pupation took place on the sides of the tin or on the leaves within it. Pupation occurred in complete darkness. The rings of yellow larval dots persist in the pupa, which bears also a few black markings along the mid-dorsal line, especially pronounced on the dorsal ridge; the protuberances on the sides of the second abdominal segment are also edged with black.

Belenois subeida zoraïda (Gaede) (fig. 3).

Pieris zoraïda Gaede, 1915, *Int. ent. Z.* **9** : 71 (♂, Neu-Kamerun).
Belenois subeida zoraïda Talbot, 1929, *Bull. Hill Mus.* **3** : 227 (♂, ♀, Haute Volta).

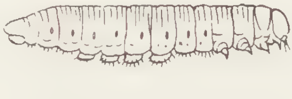
This insect is very common at Lawra and is usually found near the food-plant, *Capparis corymbosa* Tam., from which it may be beaten when at rest.

Egg.—Usually placed singly on the tips of the thorns. It is spindle-shaped and longitudinally fluted. When first laid it is white, subsequently changing to bright red and finally darkening to a plum-purple previous to hatching.

Larva.—Green, pubescent. Anal segment bifid, tipped with brown. The head bears two brown bosses, and there are two white dots between the head and the first thoracic segment. Two subdorsal white dots, edged with orange, are placed on the anterior half of each of the following abdominal segments—1, 2, 3, 4, 5, 6, 7 and 10. Many specimens, especially in the early stages, are without markings, the most persistent being those upon the head. The larva usually rests along the midrib of the leaf.

Pupa (fig. 3).—The shape corresponds with the description given by Aurivillius (Seitz, *Macrolep.* **13** : 39) of a *Pieris* pupa. The colour is green with a mid-dorsal pale buff line, and a thin lateral buff line in the abdominal section. The whole pupa is finely powdered with white. The two divisions of the bifid anal segment are small. One example which pupated in a white cardboard box was pure white.

[A specimen of the imago was not in the collection and there are no specimens from the Gold Coast in the British Museum. It may be inferred that the nominotypical race would not be the form commonly occurring in the Northern Territory of the Gold Coast.—G. T.]



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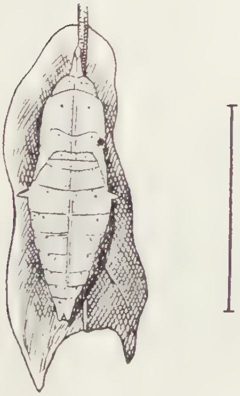

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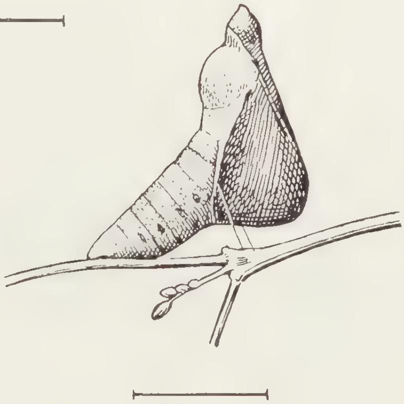


4a

Colotis vesta amelia (Luc.) (figs. 4, 4a).

Idmais amelia Lucas, 1852, *Rev. Zool.* (2) **4** : 247 (Senegal).
Teracolus amelia Aurivillius, 1910, *in* Seitz, *Macrolep.* **13** : 52.
Teracolus armitagei Dudgeon, 1916, *Trans. ent. Soc. Lond.* **1915** : 388, pl. lxiii, figs. 3, 3*a* (♂), 4 (♀) (Gold Coast).

Egg.—Shape a long ovoid, bearing longitudinal ridges and transverse markings, presenting a retiform appearance.

The eggs are laid singly on the leaves of *Maerua angolensis* D. C., and are inclined at an angle of 45 degrees or less to the leaf surface.

Larva (fig. 4).—Found in February and March, but probably feeding at other seasons also. Green, with a mid-dorsal bright yellow stripe, and many minute white dots scattered over the body. In some specimens there are one or more yellow dots on the side. Spiracles yellow.

Pupa (fig. 4a).—Yellow, inclining to terra-cotta. Wings markedly ventricose.

NYMPHALIDAE.

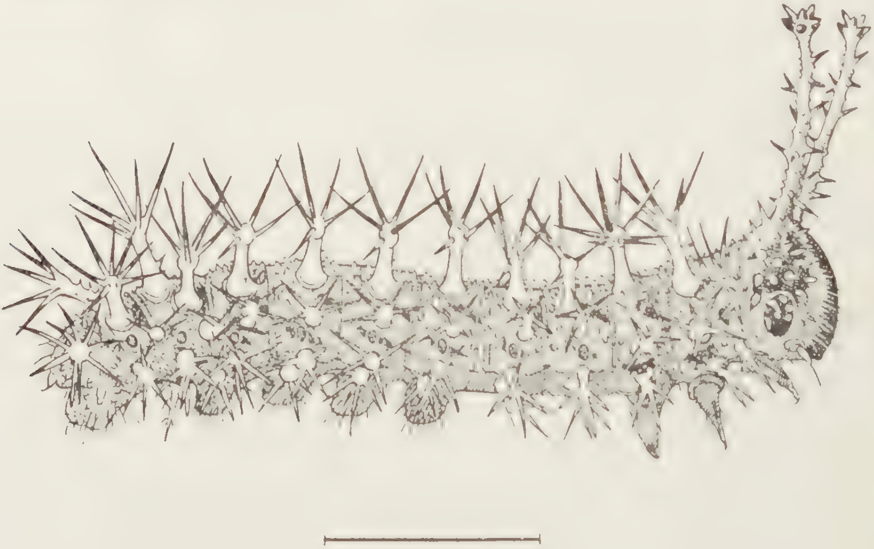
Byblia ilithyia (Drury) (fig. 5).

Papilio ilithyia Drury, 1773, *Ill. exot. Ins.* **2** : 29, pl. xvii, figs. 1, 2.
Byblia ilithyia Aurivillius, 1913, *in* Seitz, *Macrolep.* **13** : 207, t. 49*c*.

The larva is briefly described by Aurivillius (1913). In March, 1931, females were seen ovipositing on *Tragia angustifolia* Benth. The eggs were laid singly.

Egg.—Shape like a hen's egg, with the broader end affixed to the leaf. The surface is marked by longitudinal ridges, each of which bears a row of long white hairs.

Larva (fig. 5).—Dirty green, with a broad mid-dorsal yellowish stripe. Head brown, covered with small green spines, and having two long brown spines. Each segment with eight many-branched spines, dorsal and paradorsal (supraspiracular) ones black, lateral (subspiracular) and ventral ones green.



5

Precis orithya orithya (L.).

Papilio orithya Linnaeus, 1758, *Syst. Nat.* Ed. X : 473.
Precis orithya orithya Aurivillius, 1913, *in* Seitz, *Macrolep.* **13** : 226.

Larva.—Found not uncommonly at Lawra during the wet season. The larvae, at any rate when nearly full-grown, are not gregarious.

The appearance resembles that of a Vanessid larva, the body being chiefly black and covered with spines; dorsum grey-blue; lateral yellow and white stripes present.

Pupa.—Head, thorax and abdomen mostly black. There is an ill-developed mid-dorsal yellow line, also a subdorsal yellow line, and in the abdominal region there are two additional lateral yellow lines. Segments 10 and 11 are mostly yellow, the wings mainly dirty yellow. The pupal stage lasts nine days.

LYCAENIDAE.

Lachnocnema brimo Karsch.

Lachnocnema brimo Karsch, 1893, *Berlin. ent. Z.* **38** : 217 (Togo).—Aurivillius, 1923, *in* Seitz, *Macrolep.* **13** : 364, t. 65*g*.

This species, which is common at Lawra, has an extremely rapid flight. On various occasions I observed the females ovipositing close to the flowers of what I believed to be a species of jasmine. On closer examination I found that the eggs were invariably placed within an inch or less of Psyllids.

The Psyllids are usually attended by black *Camponotus* ants which appear to take no notice of these Lycaenid larvae.

In September I found the same association of ants, Psyllids and *brimo* larvae on the young flower-buds of *Bauhinia reticulata* D. C.

Egg.—Spherical, with a smooth shining surface, and ochre-coloured when freshly laid. The egg hatches in four days, during which time it changes from ochre to pink, finally becoming nearly black before hatching.

Larva.—As far as I was able to observe, the larval instars were four in number.

1*st instar.*—Head and body ochreous-brown, with a few sparse hairs. Anterior pair of legs considerably more developed than the others.

2*nd instar.*—Approximately a quarter of an inch in length. Body brown; head dark brown, with a double row of stiff black hairs along the dorsum. The anterior legs are now enormously developed, and are stretched forward in the same position as a scorpion's chelae.

3*rd instar.*—Head black. Body mottled brown, with a double row of stiff black hairs along the mid-dorsal line; a lateral row of similar black hairs below which are finer brown hairs.

4*th instar.*—Head black. Colour of body, for the most part, reddish-brown, with a certain amount of white on the sides of segments 2, 3, 6, 7, 8 and 9. The stiff hairs of each lateral row are seen to be grouped in clumps of three or four on each segment. A transverse row of hairs is borne by the prothoracic segment immediately behind the head. Spiracles white, surrounded by a black ring.

Pupa.—Suspended solely by the anal segment. It is of a squat shape, similar to *Myrina.* The abdominal section and dorsum of the thorax are rich brown; the rest of thorax, wings and head creamy white.

Virachola livia Klug.

Lycaena livia Klug, 1834, *in* Ehrenberg, *Symb. Phys.* t. 40, figs. 3–6 (Nubia).
Deudorix livia Aurivillius, 1921, *in* Seitz, *Macrolep.* **13** : 375, t. 66*e*.

Larva.—Found inside the fruit of *Gardenia erubescens* Stapf & Hutch. at Lawra, in March and April, 1930, the end of the dry season. The cavity formed by the larva was infested by black ants. The full-grown larva is three-quarters of an inch in length, the ground-colour of a dirty greenish-grey and very translucent, the spiracles black. The body is covered with fine short hairs, and with thicker hairs just below the spiracular level. A mid-dorsal sooty line is present, with much sooty pigment on the first five segments.

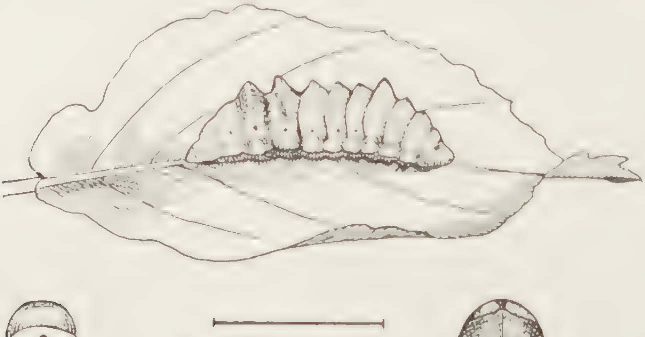
Pupa.—Brown, without markings. Pupation takes place within the fruit.

Myrina silenus (Fabr.) (figs. 6, 6a, 6b).

Papilio silenus Fabricius, 1775, *Syst. Ent.* : 531.

Myrina silenus Poulton & Lamborn, 1911, *Proc. ent. Soc. Lond.* **1911** : xcix (habits of larva, Lagos). Lamborn, 1913, *Trans. ent. Soc. Lond.* **1913** : 472 (associated ants). Aurivillius, 1922, Seitz, *Macrolep.* **13** : 378, t. 68*a*. Fleury, 1926, *Ann. Soc. ent. Fr.* **95** : 141 142 (larva, pupa) (French Guinea).—Jackson, 1937, *Trans. R. ent. Soc. Lond.* **86** : 212 (early stages, Kenya).

A common insect in the Northern Territories of the Gold Coast, most frequently seen flying round *Ficus* trees. I have found the males attracted by the flowers of *Parkia filicoidea* Welw. (the Dowadowa Tree). These insects frequently sleep in the foliage of the food-plant, and by shaking fig trees at dusk I was frequently able to disturb them. This species is most common during the second half of the dry season, from January to April.



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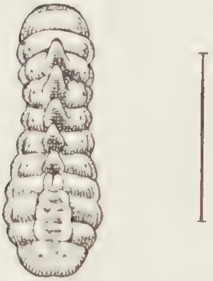
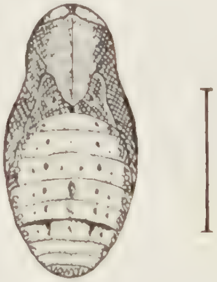


6a



6b

Egg.—Laid singly in small groups in the axils of the leaf of various species of *Ficus* including *F. ingens* (Miq.) and *F. gnaphalocarpa.* (Miq.) Steud. ex. A. Rich. Less commonly are eggs found on the stems or leaves.

Spherical in shape, and of a greyish-white colour, covered with circular depressions resembling those on a golf ball.

Larva (figs. 6, 6a). On emergence the larvae are one-sixteenth of an inch in length. Head black; ground-colour of body pale buff; a broader mid-dorsal line darker buff, and a similar but narrower lateral line; situated along the mid-dorsal line is a row of bosses, one to each segment; two stiff hairs are present on each tubercle.

Later stage. Ground-colour usually bright green and brown, apparently depending on the colour of the young leaves, which may be either. Dorsally, a row of bosses, those on the first, fifth, and sixth abdominal segments being larger than the rest; mid-dorsal line brown; subspiracular line brown except in the last instar, when it is creamy white;

anterior part of prothoracic segment, just behind the head, white, presenting the appearance of a collar. The large boss on the first abdominal segment is buff coloured; the fifth abdominal segment is buff, except for the boss, which is white, and for a small white lateral expansion, peculiar to this segment, and placed just below the level of the spiracles; the boss on the sixth abdominal segment is white; spiracles buff. The whole larva is powdered with fine black dots, and bears a few sparse hairs. The seventh abdominal segment bears a mid-dorsal gland, and the eighth a pair of extensile papillae that may be stimulated with a fine hair.

Pupa (fig. 6b).—Shape typically lycaeniform, suspended by the caudal segment and possessing no silken girdle. Abdominal segments dirty buff; wing-cases dirty olive-green; dorsum of thorax grey, and bearing a diamond-shaped depression.

I found only two wild pupae: one, on a leaf of *Ficus gnaphalocarpa*, was itself unusually green, the other on a teak tree, five yards from the nearest *Ficus*.

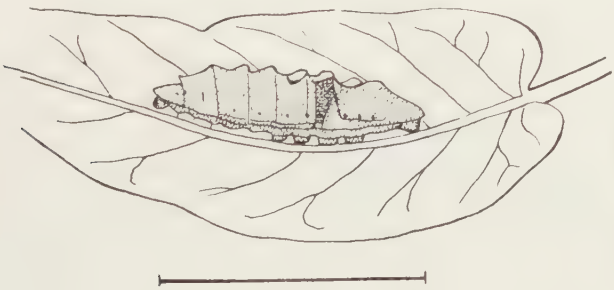
Two larvae, which hatched on 23rd February, 1930, pupated on 6th March, and emerged on 15th March, thus passing thirteen days in the larval and nine days in the pupal state. This was at the hottest time of year, when the species is most abundant. The larvae are apt to be cannibalistic in captivity.

[The descriptions of the early stages of this insect given by Fleury (1926) and by Jackson (1937) differ in some details from the description above. It may be mentioned that the pair bred by Mr. Jackson, now in the British Museum, is not quite typical of West African examples.—G. T.]

Myrina annettae Fleury (figs. 7, 7a).

Myrina annettae Fleury, 1924, *Bull. Soc. ent. Fr.* **1924** : 161 (French Guinea); id., 1926, *Ann. Soc. ent. Fr.* **95** : 141.

The imagines of this insect, as observed at Lawra, are similar in habits to *Myrina silenus*, and may be found together with that species, but in much smaller numbers.



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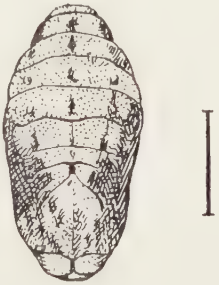


7a

Egg.—Specimens expressed from the body of a freshly killed female appeared under a lens (× 8) to be indistinguishable from those of *silenus*.

Larva (fig. 7).—The adult larva in many ways resembles *silenus*, and the diet is similar. I have found the larvae only on *Ficus ingens* Miq., but the portion of the plant eaten is the same as with *silenus*.

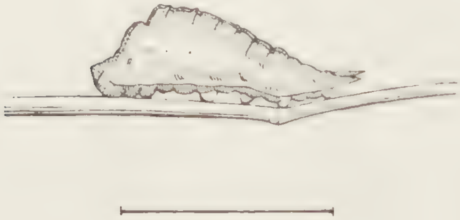
Ground-colour either green or brown with a lateral green patch. The dorsal bosses are more nearly equal in size than in *silenus*, a character which immediately distinguishes the species; there is no marked dorsal line; a subspiracular white line similar to that of *silenus*; spiracles orange; white dorsal patches on abdominal segments 4, 5 and 6, the remainder of segment 6 blackish; head brown. The green-coloured larvae are liable to become brown just prior to pupation.

Pupa (fig. 7a).—Very similar to *silenus*. Thoracic section blackish, and abdominal segments speckled reddish and black in my specimens.

[This species is very close to *subornata* Lathy, of which the type ♂ from Nigeria, and two ♀♀ from the Gold Coast, are in the British Museum. *M. annettae* is either a distinct species or it represents the South African *M. dermaptera* Wllgr., with which it more nearly agrees on the hind-wing underside, being without the discocellular spot, and the prominent post-discal spots in areas 3 to 7, seen in *subornata*.—G. T.]

Stugeta marmorea (Butl.) (figs. 8, 8a, 8b).

Aphnaeus ? marmorea Butler, 1866, *Ent. mon. Mag.* **2** : 169, fig. (White Nile).
Stugeta marmorea Aurivillius, 1923, *in* Seitz, *Macrolep.* **13** : 388, t. 68*c*.



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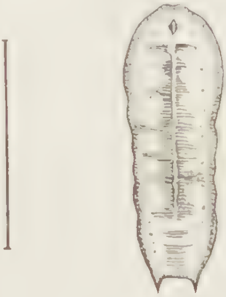
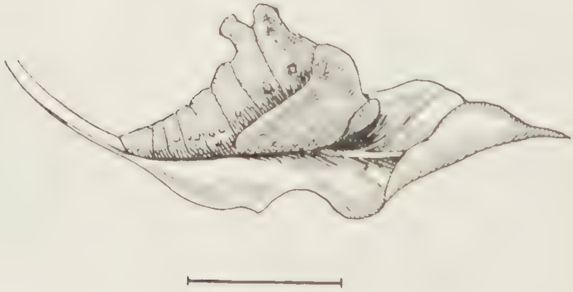


8a



8b

This insect is not uncommon in the Lawra Tumu district, strongly resembling *Argiolaus ismenias* when on the wing. The imagines are attracted to the flowers of various species of *Combretum* in company with *Axiocerses harpax* (Fabr.).

Egg.—The eggs are not difficult to find on the young twigs of *Ximenia americana* Linn. at Lawra. They are whitish in colour, slightly larger than those of *A. ismenias,* spherical, and covered with large circular depressions.

Larva (figs. 8, 8a).—On emergence from the egg the larva is green with the first thoracic segment dark brown. Each segment bears a dorsal boss from which springs a single coarse hair; these bosses are translucent and glass-like, white at the apex and deep purple at the base, forming a broad dorsal purple band; rest of body pubescent. The general appearance of this larva, both at this and at later stages, is strongly reminiscent of *A. ismenias.*

During the early stage and less commonly during later stages, these larvae often show a certain amount of red pigment, and are sometimes entirely red. This pigment persists longest as a dorsal line which, in later stages, may become brown and finally disappear. The young larvae prefer the youngest shoots and buds, which are frequently red, while the older larvae prefer the older leaves, which are more commonly green.

The full-fed larva is in general appearance very similar to that of *A. ismenias,* being green except for a lateral white line, a brownish dorsal patch, and the brown spiracles. The posterior end is bifurcate, the two divisions being more widely separated than in *ismenias,* this being the only essential difference I am able to find between these two larvae. There is a diamond-shaped depression on the back of the thorax.

Just previous to pupation these larvae completely change colour in a few hours, assuming a white ground-colour with a faint pink tinge; a very broad grey median dorsal band; a narrow subdorsal grey line, a broad lateral grey band and white spiracles.

Pupa (fig. 8b).—At first white, with longitudinal grey bands as in the larva just prior to pupation. Within twenty-four hours all these markings disappear and the pupa becomes entirely blackish. It is now a dull blackish and brown bossy pupa, very similar to *Epamera scintillans,* but with a fuller development of the two bosses on the 1st and 2nd abdominal segments respectively.

Two of my *S. marmorea* larvae pupated on green leaves, and these pupae were entirely green except for buff markings on the head, mesothorax, the two dorsal bosses, and laterally on the prothoracic and first two abdominal segments. The larva is not difficult to rear.

Argiolaus menas (H. H. Druce) (figs. 9, 9a).

Iolaus menas H. H. Druce, 1890, *Ann. Mag. nat. Hist.* (6) **5** : 29.—Aurivillius, 1923, *in* Seitz, *Macrolep.* **13** : 393, t. 67*d*.

Egg.—Found in groups of two or three on the shoots of *Loranthus Braunii* Engl. Shape pyramidal, colour white-grey and pale green with a black depressed micropylar area.

Larva.—1*st instar.* Pale green or red according to colour of food-plant. Each segment bears a mid-dorsal boss from which coarse hairs arise; rest of body clothed with extremely fine hairs; prothoracic segment with a brown patch immediately behind the head.

2*nd instar.*—No obvious hairs, otherwise similar to first stage, except that the patch on the first thoracic segment is now of a rich chocolate colour.

Later instars (fig. 9).—The larvae are extremely variable in colour, and also undergo changes during their lifetime in accordance with the changing predominant colour of the *Loranthus* leaves.

Skin very shiny with a glassy appearance. The dorsal bosses are strongly developed, especially those on the 1st, 2nd and 6th abdominal segments. Viewed from above the larva is broad in the region of the 1st and 2nd, and again at the 7th abdominal segments, thus producing the appearance of a contracted waist. The dorsal gland and papillae, often present in many *Anthene* and other Lycaenine larvae, are wanting, but there is a dorsal thoracic depression as in *A. ismenias*.

These larvae, especially in the early stages, seem to prefer eating the young unopened leaves and buds.

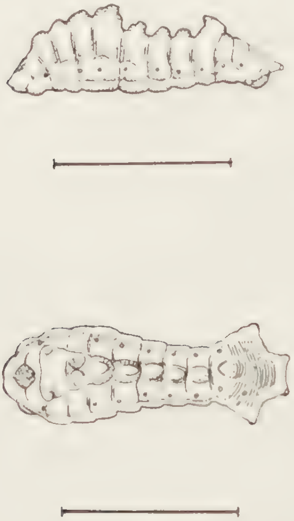
Pupa (fig. 10a).—Among my bred specimens two completely distinct forms of pupa have appeared. One, similar, if not indistinguishable from *A. ismenias*; the other, dull brown, with a very prominent backward sloping hump on the 2nd abdominal segment; this latter form is suggestive of a dead twig.

The eggs and young larvae of *menas* are not uncommon, but the later stages are hard to find, and the insect is difficult to breed.

Argiolaus ismenias (Klug) (figs. 10, 10a).

Lycaena ismenias Klug, 1834, *in* Ehrenberg, *Symb. Phys.* t. 40, figs. 1, 2 (Nubia).
Iolaus ismenias Aurivillius, 1923, *in* Seitz, *Macrolep.* **13** : 397, t. 68*d*.

The imagines may often be seen flying rapidly round and through the foliage of Shea butter trees (*Butyrospermum Parkii* Kotschy) on which *Loranthus* is parasitic.



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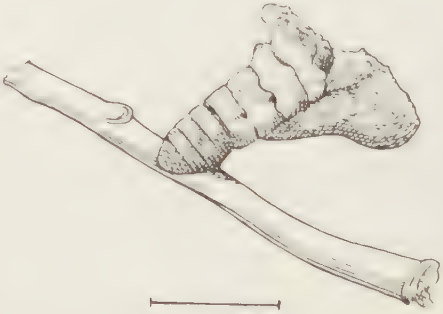


9a

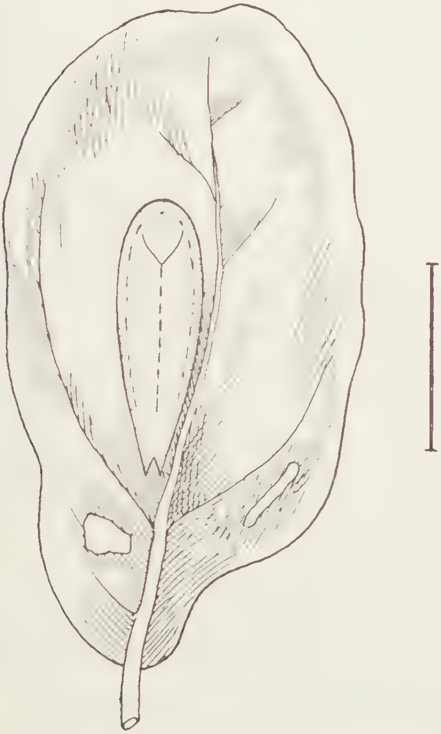
A female was observed at Lawra, ovipositing on *Loranthus Braunii* Engl., in July, 1930. Later on, many other females were seen ovipositing, and the eggs observed commonly wherever this species of *Loranthus* was to be found.

Egg.—Laid singly, usually on the upper surface of the leaves of *Loranthus Braunii*, also found on the stem and fruit. Spherical in shape, white and of a pearly lustre, without markings.

Larva (fig. 10).—On hatching yellow with a broad pink mid-dorsal line bearing long hairs. These larvae are, at all stages, extremely variable in colour. When feeding on green leaves the predominant colour is green, but when on young red or reddish leaves they are correspondingly coloured.

A larva a quarter of an inch in length exhibits on each segment a dorsal boss bearing coarse hairs. At this stage many of the larvae are green with the mid-dorsal line of a reddish plum-colour.

Full-grown larvae are triangular in section, the dorsum forming a sharp ridge. The head is so completely retracted as to be invisible except when the larva is feeding or in motion; terminal segment bifurcate. Colour bright green, powdered excessively with minute white dots; a few brown spots (not always bilaterally symmetrical) are borne on the sides; the sharp dorsal ridge is faintly edged with brown; the tips of the bifurcate anal segment rose-coloured; spiracles brown; head translucent green, eyes black. No dorsal gland or papillae are evident, but a diamond-shaped depression is seen on the back of the thorax.



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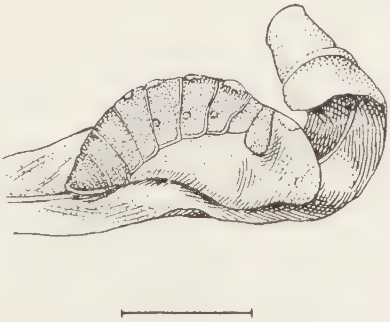


10a

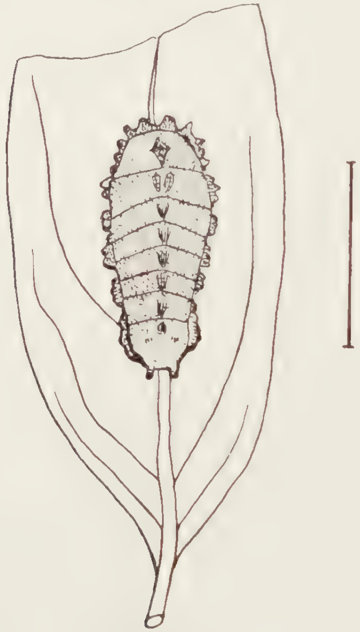
Until about three-quarters grown, these larvae most usually feed on the underside of leaves, and cause transparent patches due to the upper cuticle alone being left uneaten. In contrast with *A. menas* they prefer fully developed leaves to buds. When nearly full-grown the larva eats a section out of a leaf and then rests along the edge of the excavated portion, thus actually appearing to be part of the leaf. The prothoracic segment is folded over the leaf during mastication, after the manner of a Limacodid larva.

Pupa (fig. 10a).—This is attached to a leaf and a twig by the expanded anal segment. Green, with a mid-dorsal row of spots which are white in the centre and buff at the edges; there is one similar spot on the thorax, and three on each side of the abdomen. This pupa is almost, if not quite, identical with one form of the pupa of *A. menas.*

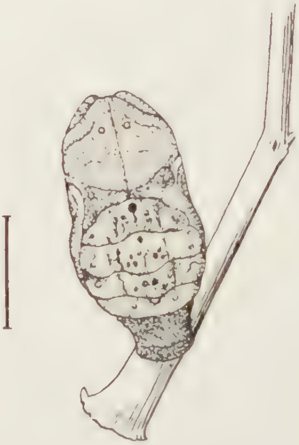
Epamera scintillans (Auriv.) (figs. 11, 11a, 11b).

Iolaus scintillans Aurivillius, 1923, *in* Seitz, *Macrolep.* **13** : 400, t. 68*e*.

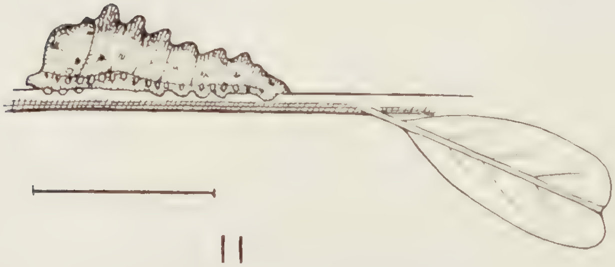
Three larvae and one dead pupa were beaten from *Loranthus Braunii* Engl. at Tumu, in February, 1931.



11b



11a



11

Larva (figs. 11, 11a).—Shape flattened. Colour brown, the skin tubercular. A lateral row of pinkish tubercles forming a frill; these tubercles mostly in small clusters of three, each segment bearing one such cluster on each side; a diamond-shaped dorsal patch on the prothoracic segment. The remaining segments, thoracic and abdominal, bear mid-dorsal bosses; head and spiracles black. These larvae are not difficult to breed.

Pupa (fig. 11b).—Shape and appearance very similar to that of *Stugeta marmorea* and to one form of *Argiolaus menas*. The colour is brown and the pupa, with its two very prominent thoracic dorsal bosses, resembles a short piece of dead twig.

Anthene lunulata (Trim.) (fig. 12).

Lycaenesthes lunulata Trimen, 1894, *Proc. zool. Soc. Lond.* **1894** : 51, pl. vi, fig. 12.—Farquharson, 1921, *Trans. ent. Soc. Lond.* **1921** : 386 (notes on larva).—Aurivillius, 1924, *in* Seitz, *Macrolep.* **13** : 444, t. 71*c* (as *lithas*, fig. h).
Anthene lunulata Jackson, 1937, *Trans. R. ent. Soc. Lond.* **86** : 223 (early stages, Kenya).

This species is common in the Northern Territories of the Gold Coast during both wet and dry seasons. Not uncommonly females may be observed ovipositing on the growing shoots of the Leguminous tree, *Parkia filicoidea* Welw. (the Dowadowa). As the insect is an extremely common one it may be suggested that its feeding habits are the cause of the predominant shape of the tree, which is much branched and spreading.

Egg.—Laid singly, in small groups. Spherical in shape, and white in colour, with the micropyle surrounded by a smooth area; the rest of the egg shows poorly developed indented markings as in some kinds of golf ball.

Larva.—In the first instar the head is black and the mid-dorsal line brown, as also the single lateral line. In my specimens the ground-colour was green, but I doubt if this is constant, as the young shoots of the food-plant are frequently red or plum-colour.

These larvae when half an inch long began to show great variation in ground-colour, some changing to dark green or plum-colour, others remaining light green until pupation.

They are frequently attended by *Camponotus* ants, and in the later stages I have observed the presence of a dorsal gland on the 7th abdominal segment, and a pair of extensile papillae on the 8th. These papillae may be caused to be everted by gently stroking the larva with a fine hair.

The larvae show a tendency to eat into the stems of the growing shoots in preference to eating the actual leaf-buds, which latter, however, are not rejected. The affected shoots usually die, but fresh shoots soon appear to replace them.

Pupa (fig. 12).—These varied in colour according to their background. Some were washy green; in others the abdominal segments were pink and the wings green, changing to grey in the course of a few days. One or two which happened to pupate on white cardboard were dirty white.

Anthene amarah (Guér.).

Polyommatus amarah Guérin, 1847, *in* Lefebvre, *Voy. Abyss.* **6** : 384, pl. ii, figs. 5, 6.
Lycaenesthes amarah Aurivillius, 1934, *in* Seitz, *Macrolep.* **13** : 445, t. 72*b*.
Anthene amarah Jackson, 1937, *Trans. R. ent. Soc. Lond.* **86** : 225–226 (early stages, Kenya).

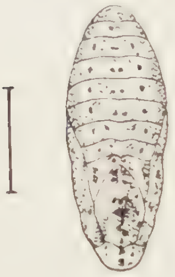
Egg.—Greenish-blue. Almost hemispherical in shape with a very flat micropylar area; covered with small projections. Laid singly on the young seedlings of the following Leguminous plants: *Dichrostachys glomerata* (Forsk.) Chiov., *Parkia filicoidia* Welw., *Acacia Rehmanniana* Schinz. and *A. albida* Del.

Larva.—Variable in colour, but usually green; head black, white, pinkish-white, or pink subdorsal and lateral lines, sparsely clothed with hairs, extend the whole length of the body. Each segment bears a lateral stripe of a darker green than the ground-colour, and sloping downwards and backwards, giving to the larva the exact appearance of the young unopened leaves of any of the above four species of plants. The 7th abdominal segment is laterally expanded.

These larvae are very frequently attended by *Camponotus* ants and possess the mid-dorsal gland and extensile papillae. In my garden, the terminal shoots of a small specimen of *Acacia Rehmanniana* Schinz. were at one time largely eaten by these larvae. The larvae were obtained in the simplest and easiest manner by looking for the ants. The association was studied by examining with a lens (× 8) a young shoot bearing a single larva and a single *Camponotus*. Whenever the ant, becoming alarmed, walked over or touched the larva, the white papillae were extended and usually a drop of fluid appeared at the mouth of the gland. On two occasions the ant drank the fluid, but when this did not occur the fluid was almost immediately withdrawn into the gland.

Pupa. Usually placed on the midrib of a leaf and attached by the anal segment and by one silken thread round the body. Colouring variable, but usually bright green with sloping creamy-yellow stripes on each abdominal segment. Three black spiracles on each side are especially conspicuous, as are the black eyes. The thoracic portion of the pupa bears a mid-dorsal creamy-white line, and a single creamy-white stripe on each side.

One pupa, which was attached to the side of a somewhat rusty breeding tin, was grey and black without any trace of green.



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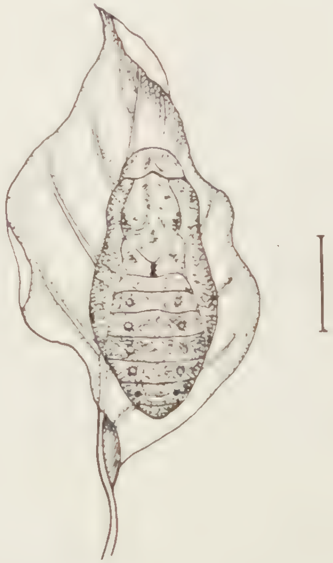

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Chilades eleusis (Dem.) (fig. 13).

Lycaena eleusis Demaison, 1888, *Ann. Soc. ent. Fr.* (6) **8** (*Bull.*) : 66 (Egypt).
Cupido eleusis Aurivillius, 1925, *in* Seitz, *Macrolep.* **13** : 490, t. 74*g*.
Chilades eleusis Stempffer, 1936, *Livre jubilaire de Bouvier* : 323–327, fig. 1 (genitalia) (systematic position).

In November, 1930, two females of this species were seen ovipositing on terminal shoots of young specimens of *Acacia albida* Deb. The ovipositor was, in every instance, inserted with some force between two young leaflets.

Egg.—Coin-like in shape, with ridges resembling the milled edge.

Larva.—Shape similar to that of *Anthene lunulata*. Green in colour, with a white subdorsal and a white lateral line. A pair of extrusible papillae were observed in the mid-dorsal line of a posterior abdominal segment.

Pupa (fig. 13).—Dark olive-green, the wings blackish with venation clearly marked.

A NOTE ON THE POLYMORPHIC VENATION OF *EPIOPHLEBIA SUPERSTES* (SELYS) (ODONATA) AND ITS PHYLOGENETIC IMPORTANCE

By Lt.-Col. F. C. Fraser, I.M.S. Retd., F.R.E.S.

In a paper on "Odonata collected in Japan" (1936, *Trans. R. ent. Soc. Lond.*, **85** : 155) I drew attention to a curious formation of the arculus in the hind-wings of a specimen of *Epiophlebia superstes* (Selys). At the time I considered this to be an abnormality, but since then I have been able either to examine or to obtain the data on venation of some ten specimens, including both sexes, and find that the supposed abnormality actually exists in the hind-wings of 40% of specimens. It is clear then that the venation in this species of archaic dragonfly must be polymorphic and that one or other of the formations found in the arculus is of a vestigial nature and therefore of some phylogenetic importance.

The species may be divided up into two forms according to the type of formation of arculus found in the hind-wings :

Forma 1 (60%). Fore-wing : the arculus is strongly angulated, forming almost a right angle, the upper and lower arms being approximately equal. The discoidal cell is very narrow, tapers to a point and is not traversed by any nervure. Hind-wing : the arculus is very oblique and only very slightly and very obtusely angulated at the junction of its two arms, of which the upper is at least twice the length of the lower. The discoidal cell broadens rapidly apically for its basal two-thirds and then tapers rapidly to a point. In addition to these differences, it will be seen that the arculus in the hind-wing makes contact with the cubitus distal to the point where the latter begins to curve downwards. In the fore-wing, the arculus makes contact with the cubitus at the summit of the curve as in all known present-day Odonata. This lack of symmetry between the arculi of the two wings is unique among recent Odonata and for a parallel to it, it is necessary to look among fossil forms.

Forma 2 (40%). Fore-wing : the arculus and discoidal cell are similar to those of forma 1. Hind-wing : the arculus has the lower arm duplicated, the more proximal one corresponding to the lower arm in the fore-wing, whilst the more distal one corresponds to the distal arm of forma 1. The discoidal cell is extremely long and narrow and only moderately dilated before the apex. If the proximal arm be taken as the true arculus, then the cell is traversed by a nervure, viz. by the distal arm of the arculus.

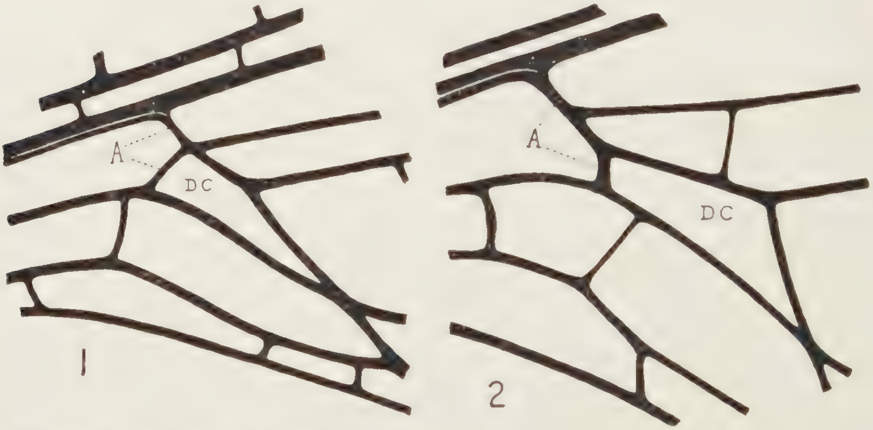
The genus *Epiophlebia* belongs to the suborder Anisozygoptera, which forms the link between the two principal suborders Zygoptera and Anisoptera. The passage from one to the other suborder is marked by the division of the discoidal cell into upper and lower cells. Thus, in the hind-wing of forma 2, this process is seen actually taking place.

As the arculus is approximately identical in fore- and hind-wings of all recent Odonata, so, by analogy, must the lower proximal arm of the arculus in the hind-wing of forma 2 be considered as part of the true arculus, since this completes the symmetry between it and the arculus of the fore-wing. The outer arm must be considered as a recent addition, and its division of the discoidal cell as the genesis of the Anisopterous condition.

The course of evolution may be divided into five stages as follows :

1. The arculus incomplete below and the discoidal cell open at the base in fore- and hind-wings. (As found in the Protozygoptera.)
2. The discoidal cell of hind-wing closed at base by completion of the arculus; that of fore-wing still open and arculus incomplete. (As found in *Hemiphlebia* and *Chorismagrion* among recent Odonata and *Liassophlebia*, etc., among fossil forms.)
3. Discoidal cells of both wings closed and both arculi complete. (As found in all living Zygoptera save *Hemiphlebia* and *Chorismagrion*.)
4. Discoidal cell of hind-wing divided up into two cells by a traversing nervure; that of fore-wing still undivided. (As found in forma 2 of *Epiophlebia* and *Heterophlebia* (Liassic).)
5. Discoidal cells of both fore- and hind-wings divided up into two cells by a traversing nervure. (As found in all species of the suborder Anisoptera.)

There still remains to be explained the formation of the arculus in the hind-wing of forma 1 of *Epiophlebia*, especially as this is slightly the more common form met with.



Figs. 1–2.—1. Discoidal area of fore-wing of *Epiophlebia superstes* (Selys); 2. the same of the hind-wing of forma 1, *Epiophlebia superstes.*

Among fossil species belonging to the suborder Anisozygoptera a marked difference is often found between the arculi of the fore- and hind-wings; thus in *Heterophlebia* the arculus of the fore-wing is strongly angulated as in *Epiophlebia*, whilst that of the hind-wing is almost straight or its angle very obtuse as in the hind-wing of forma 1, *Epiophlebia superstes*. It would appear that in this transitional stage from the suborder Zygoptera to the suborder Anisoptera, two alternative venational schemes presented themselves: the one exemplified in forma 1 of *Epiophlebia* in which the dividing nervure of the discoidal cell superseded the place of the lower arculus, the reformed arculus then becoming very obtuse and straight and the discoidal cell reverting to its single-celled condition; the other exemplified by forma 2 of *Epiophlebia* in which, following on the division of the discoidal cell into two, the lower arculus persisted. The conversion of the two new cells thus formed into the Anisopterous triangles has been so well explained by Needham as to need no repetition here. It is a fortuitous circumstance which has not only preserved the living fossil *Epiophlebia superstes*, but has also conserved two invaluable links of evolution to show how the modern Anisoptera came into being.

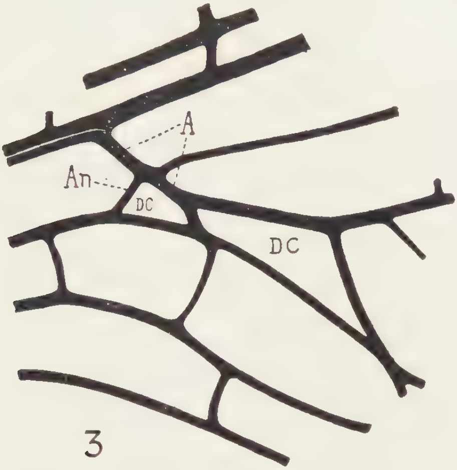


FIG. 3. The same of the hind-wing of forma 2. *A*. arculus, *An*, additional nervure or proximal lower arm of arculus, *Dc*, discoidal cell.

BOOK NOTICE.

Grundriss der Insektenkunde. By Dr. HERMANN WEBER. Jena, 1938 (Verlag Gustav Fischer). pp. xii + 258, 154 figs. Price RM. 13.50, bound.

This is a text-book of entomology designed for students of zoology who do not intend to specialise in Entomology. It is not merely a shorter edition of the *Lehrbuch der Entomologie* by the same author, but an entirely new book. The first half (123 pages) deals with anatomy and physiology; there follow 70 pages on general systematics and 50 pages on ecology (including a short section on insects in relation to man). The illustrations, of which two-thirds are new, are of the same high standard of excellence as in the author's previous publications. In the systematic section he has introduced a new technique by which external and internal structure are successfully represented in a single figure.

THE NUMBER OF MOULTS IN THE CYCLORRHAPHOUS FLIES (DIPTERA)

By Gottfried Fraenkel.

Communicated by Dr. O. W. Richards, F.R.E.S.

If, shortly before the evagination of the head takes place, the pupa of a fly is very carefully dissected out from the puparium by cutting away very small pieces of the puparium by tangential cuts with a razor blade, the pupa is found to be enveloped in an extremely fine sheath. This sheath is very thin, fragile and hardly visible. It is almost impossible to remove the pupa from the case without tearing this sheath, but it can be made clearly visible by the following method: part of the puparium is carefully dissected off in the way described above, and when this is done the pupa is boiled for a few seconds in Hematoxylin Delafield. By this process the sheath becomes stained and in addition the pupa is coagulated and fixed. By doing this in a great number of cases it was found that this sheath envelops the whole abdomen, including those parts of the legs and wings which have grown beyond the thorax, and lies freely between the puparium, which is identical with the cuticle of the third larval instar, and the pupal skin. In the later stages it becomes firmly attached to the inside of the pupal case and cannot any more be traced, except for a few small bits of it, which become attached to the dorsal end of the abdomen of the pupa and to the main larval tracheal trunks after they have become withdrawn through the hind spiracles. One observes there small fragments of an iridescent membrane.

Application of the chitosan tests shows that the sheath consists of chitin: boiling for 1 hour in conc. KOH at 160° C. in a glycerol bath does not change it visibly. After this treatment it dissolves in dil. acetic acid and reprecipitates in H_2SO_4 1% (Chitosansulfate). It also stains distinctly violet with iodine.

It is difficult to trace the origin of this sheath backwards. The content of the puparium cannot be dissected out alive and unhurt from the pupal case before it reaches the stage in which the sheath is already formed. About 16 hours after the formation of the white pupa of *Calliphora*, *Lucilia*, *Phormia* or *Sarcophaga*, the larval cuticle, now the puparium, becomes detached from the underlying cuticle by a moult. The exact date of this moult cannot be ascertained, since dissection alive is not possible in this stage, and any fixation by heat or alcohol tends to bring about this separation presumably before the time it would occur naturally. As is the case in every insect moult, at the time of the separation of the old and new skin, the hypodermis has already secreted a new cuticle which is, in this case, an extremely thin structure. This new skin, which may be called the prepupal cuticle, envelops the whole abdomen, which at this stage is still almost unchanged from the larval abdomen. In this stage tiny legs and wings are already visible on the ventral side of the thorax, but have not yet grown beyond the thorax. Now a second moult occurs inside the puparium, by which the prepupal cuticle covering the abdomen becomes detached from the hypodermis. The hypodermis secretes a new and much thicker cuticle, which is known as the pupal cuticle, and is left behind in the puparium when the fly emerges. As the legs and wings grow backwards, first into the stage in which the evagination of the head occurs, and later up to the

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tip of the abdomen, they grow into the space between the prepupal and the pupal cuticle. One may therefore distinguish in the later stages of the pupa four cuticles, one inside the other, the puparium, the prepupal, the pupal and the adult cuticle. It may be convenient to refer to these three moults, by which the four layers of cuticle are formed, as the prepupal moult, the pupal moult and the adult moult. These three moults would be homologous in, say, a lepidopteron to the moult which leads to the last larval stage, the moult which converts this into the pupa and the moult which precedes emergence of the adult.

Shortly after the time when the head is evaginated, the sheath becomes firmly attached to the inside of the puparium. It can, however, be separated from it again, by treating the puparium with diaphanol (solution of ClO_2 in acetic acid, which is used in microtechnique for softening and decolorising chitin). On such treated puparia it is easy to determine the extension. It starts slightly in front of the circular line of cleavage at the segmental border, which separates the 3rd thoracic from the 1st abdominal segment and is actually firmly attached here to the pupal case and does not separate from it, even after very prolonged treatment with diaphanol (I number the segment which carries the anterior larval spiracles and is the first visible in the pupa as the 1st thoracic segment and the three following as the 2nd and 3rd thoracic and the 1st abdominal segment). Behind this line of attachment it separates completely from the puparium exactly as it does in the young pupa. If one look at the inside of a pupal case which has been emptied before the fly emerged without removing the anterior part of it which normally splits off during emergence, one may easily see a distinct difference in the appearance of the inside of the puparium. This is shiny in the abdominal part, where the sheath is attached to it, and matt in the thoracic part where this is not the case. From this it seems certain that the pupal moult occurs only in the abdomen. This is not surprising in view of the fact, that, according to Pérez and others, the mechanism of the formation of the pupal skin is different in the thorax and the abdomen. Before these facts about the real extension of the sheath were known to me, I had tried vainly to find a stage in which the whole of the prepupal body was enveloped by it and the sheath extended freely over the roots of the wings and legs in the thorax.

The existence of a cuticle lying between the larval and pupal cuticle has never been observed in flies, except in one particular case by Snodgrass, who described it in full detail from the Apple Maggot, *Rhagoletis pomonella* Walsh, without discussing further whether it occurred also in other flies. In *Rhagoletis pomonella* during the first twelve hours after the formation of the puparium, the puparium separates from the body by a moult. " The object disclosed in the puparial capsule of the apple maggot at this stage has no character suggesting a pupa. There are no signs of legs or wings; the form is a mere replica of that of the puparium." By this moult " the maggot of the 3rd instar has changed by a puparial moult not to a pupa, but to a fourth-instar larva, an intrapuparial, prepupal larval stage." The cuticle of this stage envelops the whole body and is not, as in the flies investigated by me, restricted to the abdomen. After it becomes detached from the proper pupa, it lies—according to Snodgrass (Pl. 5, fig. F)—loosely between the puparium and the pupa and envelops the whole of the pupa. Leaving aside now the question of its extension, this moult has been found so far in two different families (TRYPETIDAE and CALLIPHORIDAE) of the Cyclorrhapha and therefore seems to be a regular feature in the development of this group.

One remarkable outcome of the discovery of this additional moult in flies is the fact that by this the number of moults in the cyclorrhaphous flies is shown to be the same as in Nematocera. Mosquitos, *e.g.*, have four larval instars, which are attained in three moults. By the fourth moult they are transformed to the pupa and by the fifth moult to the adult (Howard, 1912). Exactly the same is the case for TIPULIDAE (Sellke, 1936). The cyclorrhaphous flies have three larval instars only, which are attained in two moults. The cuticle of the 3rd instar becomes the puparium by a process of contraction, darkening and hardening, which is generally called pupation. The third moult is the prepupal moult, by which the puparium becomes separated from the hypodermis; the fourth moult is the pupal moult, which separates off the thin sheath, described in this paper, from the now-completed pupa; and by the fifth moult the emerging adult frees itself from the pupal cuticle.

This scheme is, however, not of general validity for the whole of the Diptera, for, from the little known about the number of moults in Brachycera, this seems to be very variable. Cameron (1931) recorded in the Tabanid *Haematopota pluvialis* the variable number of seven to ten larval instars. *Bombylius pumilus*, which lives as a parasite on the larva of the bee *Colletes daviesana*, has three larval instars, according to Nielsen (1903). These were, however, counted in a culture, which was started from small collected larvae and it is possible that the first larval instar, which is generally of a very short duration in Diptera, was overlooked. In ASILIDAE, Melin (1923), in spite of very thorough studies, was not able to establish the number of moults. In *Vermileo comstocki* (RHAGIONIDAE) Wheeler (1930) recorded at least five moults; the true number has not been established.

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A FURTHER CONTRIBUTION TO THE ECOLOGY OF *ALEURODES BRASSICAE* WALK. (HEMIPTERA)

By Colin Gasking Butler.

1. *Introduction.*

In a previous paper (Butler 1938) the relationship between *Aleurodes brassicae* and the chief biological factors of its environment have been discussed in detail. The present paper is mainly concerned with the relationship of this insect and the physical factors of its environment.

All the Whiteflies used in these experiments were derived from specimens collected in a garden in Cambridge during 1935, unless a definite statement in the text is made to the contrary. The work was undertaken at the University Entomological Field Station and the Zoological Laboratory, Cambridge, while I held a scholarship from the Ministry of Agriculture and Fisheries.

I would like to take this opportunity of acknowledging my indebtedness to Dr. A. D. Imms, F.R.S., for his constant advice and encouragement.

2. *The parasites and predators of* A. brassicae.

A note has already been published (Butler 1936) recording the occurrence of two species of Chalcid parasites of *A. brassicae*, *Encarsia partenopea* Masi and *E. tricolor* Förster, in Cambridgeshire. The latter species, according to Dr. C. H. Ferrière, had not previously been recorded in Britain, but is common in Italy.

From laboratory observations made on the coldhardiness of these Chalcids, it appears that very few, if any, of them can live through the winter in this country, since neither the adult nor pupa can withstand a temperature of — 2° C. for as long as six hours. From this it would appear possible that when, as by 30th September, 1935, they have become abundant in the field, it is due to the importation of parasitised pupae of *A. brassicae* on " greens " from Italy. This hypothesis seems to have been upheld in 1936, since very few of these Chalcids were found in the field, either in localities where they had been abundant in 1935 or in other places. This was possibly due to the death of the progeny of those present in 1935 in the hard winter, and failure of reinfection owing to the application of political sanctions to Italy, which restricted the entry of Italian produce into this country.

A large stock of *Encarsia partenopea* was, however, kept alive for some time in a heated glasshouse at the University Entomological Field Station, and experiments were conducted to determine the degree of control they could exert over *A. brassicae* in the field if present in sufficient numbers during the summer months. It was found that at 18° C. and 80% relative humidity, which appears to be about the optimum, the life-cycle of *A. brassicae* takes about thirty days to complete, whereas that of *Encarsia partenopea* at this temperature and humidity takes only ten days. A female *E. partenopea* lays between 150 and 200 eggs in the course of her life, and only attacks the late larval stages of *A. brassicae*. From these observations it would appear that, under suitable conditions, *E. partenopea* could exert a very considerable measure of control over the numbers of *A. brassicae* in the field. The following field observation seems to confirm this view. In July 1935 a field of mixed " greens " was found to be very heavily infected with *A. brassicae*, and on two plants only were any parasitised pupae found, although every plant was carefully examined on each of two occasions within eight days. By the beginning of September, however, every plant in the field had a large number of parasitised pupae of *A. brassicae* upon it, and it was estimated from counts made at this time that at least 80% of the pupae of *A. brassicae* present were parasitised.

Not many predators of *A. brassicae* have been discovered, and these probably only feed upon the Whitefly when it is very abundant, or when their usual source of food, such as APHIDAE, is scarce. The larvae of the Syrphids, *Syrphus cinctus* Fallén and *S. auricollis* Meigen, have been observed feeding on the pupae, third instar nymphs, and also on the adults. A Cecidomyid larva (which Dr. H. F. Barnes thinks may be *Phaenobremia* sp.) was found in many places feeding upon the late larvae and adults of *A. brassicae* in September 1936.

Tits and other small birds, that have been observed hunting over cabbage plants bearing no insects except *A. brassicae*, were, so far as could be determined, feeding on the Whitefly.

3. *The effects of temperature on the adults of* A. brassicae.

(a) *High temperature.*

In the following experiments a specially modified Rothamsted controlled-environment chamber was used. This chamber differed but slightly from that described by Wilson (1937).

Twenty-five newly emerged adult male Whitefly and twenty-five similar females were used in each experiment; sixteen experiments being conducted in all. In these experiments, on the effect of high temperature on the survival of *A. brassicae*, the temperature range explored was from 25° C. to 40° C. In all the experiments the atmosphere was maintained at a saturation deficiency of 2·37 mm. of mercury, and the fan in the chamber was kept running sufficiently fast to cause the plants, on which the Whitefly were liberated, to bend over slightly. Young Brussels Sprouts plants were used as host-plants for the Whitefly, a wire-gauze cage being placed over each plant. At each temperature ten plants were placed in these cages; five plants each carrying five adult males, and five plants each carrying five adult females. The experiments were each allowed to run for five days, at the end of which time the Whitefly still remaining alive were counted. Control experiments were run at 20° C. and 2·37 mm. of mercury saturation deficiency at the same time. The results obtained are given in the table on p. 163.

From the table it may be seen that a small percentage (22%) of *A. brassicae* adults can withstand a temperature as high as 37° C. for five days, and that in one case a male withstood a temperature of 39° C. for this length of time. A gradual falling off in the numbers that lived for five days at temperatures above 31° C. is also very noticeable. A temperature between 28° C. and 32° C. would appear to be about the optimum for *A. brassicae* adults.

(b) *Low temperature.*

During October and November 1935 a series of experiments on coldhardiness was conducted on the eggs, pupae and adults of *A. brassicae*. The series was repeated in May 1936, when the Whiteflies were beginning to become active in the field once more. Except for the adult males and the eggs, all the Whiteflies used in these experiments were collected in very sheltered places in the field the day before use. Various low temperatures were maintained in a refrigerator in which the saturation deficiency of the atmosphere was always kept as near zero as possible.

Temperature. ° C.	No. of ♂♂ alive after five days. (Exp.)	No. of ♀♀ alive after five days. (Exp.)	No. of ♂♂ alive after five days. (Control)	No. of ♀♀ alive after five days. (Control)
25	25	24	25	25
26	24	25	25	25
27	25	25	25	24
28	25	25	25	24
29	25	23	25	25
30	23	22	25	25
31	24	24	23	25
32	21	19	25	25
33	18	14	25	24
34	20	16	25	25
35	15	11	25	22
36	12	5	24	25
37	9	2	24	25
38	0	0	25	25
39	1	0	23	25
40	0	0	25	25

TABLE 1.—The effect of temperatures from 25° C. to 40° C. on the survival of adult male and female *A. brassicae*, the saturation deficiency of the atmosphere being maintained at 2·37 mm. of mercury throughout each experiment.

In each experiment 500 male Whiteflies, reared from pupae collected in very sheltered places in the field, and 500 female Whiteflies, were liberated on a freshly cut cabbage leaf placed in a large hurricane-lamp glass standing on a Petri dish and covered with cellophane. Five hundred pupal Whiteflies, collected in the field, were placed in another hurricane-lamp glass, and 100 eggs, newly laid in the laboratory, were also used in each experiment. In every case the experimental insects were placed in the refrigerator at room temperature (approximately 13° C.), and the temperature was then lowered very slowly to the lowest point required, at which it was maintained for twelve hours. It was then allowed to rise gradually to room temperature once more. The number of adults still alive was counted, and the number of eggs and pupae that hatched within three weeks at 18° C. was also determined. Control experiments were run simultaneously in an incubator in which the saturation deficiency of the atmosphere was maintained at about zero and the temperature at 18° C. The following table gives the results of the series of experiments conducted in October and November 1935 and May 1936.

From table 2 it will be seen that low temperature causes a heavy mortality among the eggs of *A. brassicae*; but even when the temperature drops as low as — 15° C. during October and November it does not have a great effect on the survival of the pupae and adult males and females. In May, however, the percentage of the pupae and males and females that survived subjection to the lowest temperatures was reduced by nearly 50%. It has also been found that a mortality of nearly 90% occurs if the pupae and adults of *A. brassicae* are subjected to a temperature of — 15° C. in August. It may therefore be concluded that during the autumn months coldhardening occurs until, by the end of

Temp. ° C.	% of eggs that hatched after 12 hours at this temp.	% of control eggs that hatched	% of pupae from which adults emerged	% of control pupae from which adults emerged	% of adult ♂♂ that lived	% of control ♂♂ that lived for two days at 18° C.	% of adult ♀♀ that lived	% of control ♀♀ that lived for two days at 18° C.	Month in which exp. took place
+3	98	98	91·2	96·2	99·8	99·6	99·6	99·4	October and November 1935
+2	91	98	92·6	98·4	98·6	99·2	99·4	99·2	
+1	[illegible]	97	95·4	87·4	99·2	99·2	99·2	99·4	
0	85	99	94·4	88·8	99·2	98·6	99·2	98·8	
−1	71	98	87·8	98·2	99·8	99·2	95·8	99·2	
−2	55	94	88·8	88·0	98·4	99·6	89·6	99·4	
−3	47	84	92·4	91·6	99·2	99·4	92·2	97·6	
−4	43	91	78·8	87·0	99·4	99·2	98·8	99·2	
−5	28	97	88·6	87·8	89·6	99·2	89·6	98·8	
−6	25	85	90·2	92·8	95·8	98·4	92·8	99·4	
−7	8	88	94·4	98·8	99·2	99·2	99·4	99·6	
−8	4	90	84·2	96·6	98·2	99·6	99·2	99·0	
−9	1	94	92·2	86·8	99·4	99·2	89·4	99·0	
−10	0	81	78·8	88·2	99·2	99·0	99·2	88·6	
−11	1	97	96·4	94·4	89·4	99·6	95·6	88·0	
−12	0	98	78·4	96·2	92·8	99·4	96·0	98·6	
−13	[illegible]	94	86·8	95·4	97·8	99·2	97·2	99·4	
−14	[illegible]	84	88·2	89·4	91·4	98·8	91·8	99·0	
−15	0	90	88·2	88·6	90·4	99·4	99·0	98·4	
+3	96	84	95·4	87·2	91·6	99·4	94·8	99·6	May 1936
+2	[illegible]	97	94·8	92·4	91·4	99·2	87·8	99·2	
+1	91	98	88·8	92·6	89·6	99·6	91·4	98·8	
0	90	95	90·8	88·8	99·2	99·4	99·0	99·8	
−1	84	96	88·4	91·4	97·8	97·8	80·6	100	
−2	82	97	88·2	88·6	98·8	96·4	87·4	99·8	
−3	68	91	88·8	92·8	83·6	99·8	88·6	98·4	
−4	40	90	98·4	84·8	80·4	99·2	74·6	99·4	
−5	22	90	76·8	82·4	82·8	99·4	68·6	99·4	
−6	23	92	83·8	86·2	79·6	99·2	78·4	99·2	
−7	10	97	71·4	98·2	70·0	96·4	80·8	97·8	
−8	7	94	84·2	88·6	76·4	99·2	71·8	98·6	
−9	2	95	64·8	88·6	72·2	98·4	84·4	99·0	
−10	1	97	70·4	96·8	75·6	97·6	73·8	99·2	
−11	0	98	78·2	88·4	68·6	99·6	61·2	99·8	
−12	0	98	48·8	88·8	61·8	99·2	60·8	98·6	

TABLE 2.—The percentage survival of eggs, pupae and adult male and female *A. brassicae* at low temperatures and at zero saturation deficiency.

November, a very considerable degree of coldhardiness has been acquired by *A. brassicae*. By May of the following year, however, a large proportion of this coldhardiness has been lost once more, and about 50% of the pupae and adults die when subjected to really low temperatures.

One further point of interest arose from this work, namely, that while unmated males, such as those used in the experiments described above, will stand great cold, males that have mated exhibit considerably less coldhardiness, and about 70% of them die when subjected to a temperature of −10° C. This presumably accounts for the fact that few, if any, adult males are to be found in the field after November.

(c) *The effect of different temperatures at a constant saturation deficiency on the rate of oviposition of* A. brassicae.

A constant saturation deficiency of 2·4 mm. of mercury was maintained throughout a series of experiments at different temperatures. In each experiment 100 newly emerged male Whiteflies and 100 similar females were liberated upon four cabbage plants placed in the modified Rothamsted controlled-environment chamber. The experiments each lasted for a period of ten days, at the end of which time the total number of eggs that had been laid was determined. The results are expressed in the following graph :—

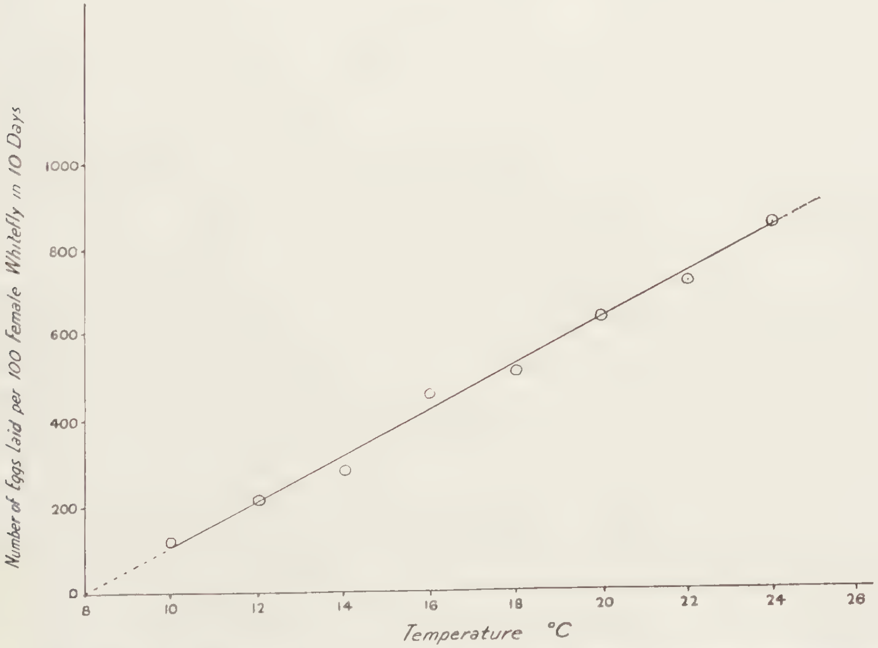

Fig. 1.—Graph showing the results of experiments on the effect of different temperatures at a constant saturation deficiency of 2·4 mm. of mercury on the rate of oviposition of *A. brassicae*.

From this graph it will be seen that the number of eggs laid per female Whitefly in ten days was directly proportional to the temperature over the range of temperature explored (*i.e.* 10° C.-24° C.). The relation between temperature and number of eggs laid is that an increase of 1° C. is associated with an increase of approximately 0·5 eggs per female in the ten days.

4. *The effects of different humidities at a constant temperature on the rate of oviposition of* A. brassicae.

Experiments similar to those used in studying the effects of different temperatures at a constant saturation deficiency were conducted in a modified Rothamsted controlled-environment chamber to determine the effects of different saturation deficiencies at a constant temperature of 18° C. on the rate of oviposition of *A. brassicae*. At the end of a ten-day period the total number of eggs that had been laid by 100 newly emerged females in association with 100 similar males was determined. Experiments were conducted over a large range of saturation deficiency, but in every case between 450 and 500 eggs were laid. From this it would appear that humidity has no effect on the rate of oviposition of *A. brassicae*; but it seems probable that, provided that the host-plant is transpiring normally, *A. brassicae* living close to the leaf surface is always subjected to an atmosphere which is very nearly saturated with water vapour whatever the humidity of the macro-environment, provided that the wind velocity is not too great. Consequently, it is possible that throughout these experiments the Whiteflies were actually living at a temperature of 18° C. and a saturation deficiency of approximately zero, so that in the number of eggs laid per 100 females in ten days only small fluctuations were found. These fluctuations may well be explained in the greater part by variations in the number of female Whiteflies which reached the host plants when liberated in the chamber in each experiment, and by individual variations in fecundity. That the Whiteflies are almost certainly living in a micro-environment in which the humidity is always high whatever the conditions existing in the external environment was shown experimentally by Ramsay, Butler and Sang (1938) by means of a special hair hygrometer capable of measuring the humidity of a layer of air 0·5 mm. above a leaf surface, and a micro-evaporimeter. Unfortunately a cabbage leaf could not be used readily in these experiments, but, since the rate of transpiration per square inch of leaf surface (measured with a potometer) of the leaf of *Tulipa gesneriana* is very similar to that of a cabbage leaf, it seems probable that the results obtained with a leaf of this plant are also applicable to the cabbage leaf. It was shown that with a wind velocity of 1·6 feet per minute, the general atmosphere having a temperature of 21° C. and a 10% relative humidity, the humidity gradient could be detected up to a height of 1·2 cm., and reached 94% relative humidity 0·5 mm. above the leaf surface and 70% relative humidity 2 mm. above the surface in many experiments. It should further be pointed out that *A. brassicae* always lives on the undersurface of the leaves of its host-plants, where it is more protected and the humidity gradient is less likely to be rendered steeper by wind action.

5. *The migrations of* A. brassicae.

This subject is best considered under three heads, namely :—

(*a*) Factors which cause *A. brassicae* to migrate.
(*b*) Laboratory experiments on the physical factors of the environment necessary for migration to take place.
(*c*) Field observations on the physical factors of the environment during migrations of *A. brassicae*.

(a) *Factors which cause* A. brassicae *to migrate.*

One of the most obvious reasons for desertion of one host-plant for another is the death of the former plant. This was observed to be the case where the death of a plant was brought about by severe infection with the root-fly, *Hylemyia brassicae* Bché., which eats off the young rootlets and burrows in the older roots, causing rotting. Death was also caused artificially by cutting off the root of a growing plant, and, under both these conditions, 85% of the adult Whiteflies present on the plant deserted it as soon as the result of the injury became manifest. Desiccation of the host-plant for any reason was also found to cause the great majority of the Whiteflies present to desert the plant.

Another important factor which causes *A. brassicae* to desert its host-plant is overcrowding of the adults. If too many adult Whiteflies are liberated on a healthy plant they tend to jostle one another in their activities on the leaf surface. This accidental jostling causes one or both of the participants to leave the plant and fly off into the air. Often they re-alight on the same plant, but frequently they fly right away. The concentration of adult Whiteflies necessary to cause this overcrowding effect during the summer months was found by experiment to be a number of more than six adults per square inch of available leaf surface. Above this the number of migrations which took place increased in a manner directly proportional to the number of insects above six per square inch of leaf surface.

In addition to this overcrowding effect, the overcrowding frequently either killed or damaged the plant severely, which, as mentioned above, tends to cause desertion of the host-plant. Both of these effects could be caused by the additional presence on the leaf surface of insects other than Whiteflies, such as the Aphid, *Brevicoryne brassicae.*

Overcrowding of the developmental stages does not cause desertion of the host-plant, as of these the first instar larva alone is mobile, and that only in a very restricted way. It can move a short distance on the leaf surface itself but cannot, in normal circumstances, migrate to a fresh host-plant. Death or severe damage to the host-plant kills the majority of larvae present.

Destruction of the host-plant by man, or knocking of the host-plant by animals, also frequently causes some of the adults present to migrate.

Mention has already been made in a previous paper (Butler 1938) of the autumnal migration of adult *A. brassicae* to places of shelter on the available host-plants. Such places as the crannies between the heart leaves of Broccoli, or the depressions on the undersurfaces of the overlapping leaves of Savoy plants and the crinkled outer edge of Curly Kale being the ones most frequently chosen. In the spring on the advent of warmer weather the adult females that have spent the winter in the overwintering clusters, either spread out over the leaf surface once more or, more frequently, migrate to fresh host-plants.

(b) *Laboratory experiments on the physical factors of the environment necessary for migration to take place.*

The following experiments were all conducted in a modified Rothamsted controlled-environment chamber (Wilson 1937) in which the temperature, wind velocity and humidity of the environment could be controlled accurately.

Experiments were conducted in the cabinet in order to determine the optimum conditions for successful migration of *A. brassicae.* In these experiments six cabbage plants were used and a large number of adult Whiteflies of both sexes liberated on them. The atmosphere was kept at a temperature of

20° C. in the first series of experiments. The humidity was maintained at a saturation deficiency of 8·75 mm. of mercury for the first seven days. At the end of this time the plants, which had not been watered at all since being placed in the chamber, had dried up and shrivelled considerably, and it was known from field observations, that the Whiteflies would, under favourable conditions, have left the plant by this time. Only some 5% of them had done so and these were clustered on the glass windows of the cabinet. The humidity of the atmosphere was then raised slowly and the reactions of the Whiteflies carefully noted. At a saturation deficiency of 5·25 mm. of mercury the Whiteflies showed definite signs of migrating, appearing restless and taking short flights around the plants. As the humidity was slowly raised in stages to a saturation deficiency of 3·5 mm. of mercury more activity was observed, until, by the time it had reached 3·1 mm. of mercury, about 30% of the Whiteflies had left the plants and were clustered on the glass windows. As the humidity continued to be raised gradually, increasing numbers of Whiteflies migrated right away from the plants, and by the time a saturation deficiency of 0·87 mm. of mercury had been reached, only eleven, out of the original six hundred, Whiteflies were left on the plants. These observations were repeated with different experimental insects five times, and in each case similar reactions were observed. It would seem, therefore, that a high atmospheric humidity is the best condition for migration.

In another series of experiments the humidity was maintained at a saturation deficiency of 0·8 mm. of mercury and the temperature was raised gradually from 5° C. to 35° C. It was found that complete migration took place as soon as the temperature was over 8° C.

(c) *Field observations on the physical factors of the environment during migrations of* A. brassicae.

A large number of measurements of the temperature and humidity and estimation of the wind velocity were made in the field in 1936 and 1937 during the autumn and spring migrations of *A. brassicae*.

No migration was observed to take place when there was much wind. The greatest migrations, when thousands of insects were in the air at once, always occurred on still days. Temperature appeared to be a most important factor influencing migration: no migration ever being observed when the general atmospheric temperature was below 6° C.

The effect of humidity on the migration of *A. brassicae* in the field is not very definite. It does appear, however, that in the cases studied the vast majority of the migrations (85·7%) took place at saturation deficiencies of less than 5·0 mm. of mercury, which is in general agreement with the results obtained in the laboratory.

The following table shows the temperature and humidity, both being taken four feet above the ground, during 105 occasions when Whiteflies were seen migrating naturally in large numbers from October 1935 to November 1937.

6. *Conclusions. The extent to which the biotic and physical factors of the environment influence* A. brassicae *in nature.*

All the physical factors of the environment discussed appear to influence the responses of the insect throughout its life, to a greater or lesser degree.

The gradual decline in the mean daily temperature of the atmosphere through the autumn months probably causes the insects to obtain some degree of cold-

Saturation deficiency in mm. of mercury.

Temp. in degrees C.	0·4	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·8	6·0	6·2	6·4
17															1																
16			1													1															
15			1				3			1						1													1		
14																	1														2
13									1								1														1
12		2			7		3			4												1					2				
11		2			5		4			8						1	1			1					1		3			2	
10											1		1				1					3		1							
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TABLE 3.—The number of occasions on which migrations of *A. brassicae* took place in the field at observed temperatures and saturation deficiencies.

hardiness. This drop in temperature also causes cessation of oviposition and the formation of the overwintering clusters of Whiteflies in the most sheltered places on available host-plants. In this connection it also leads to migration to host-plants, such as the Savoy cabbage, which, although not favourite summer hosts, afford the greatest measure of protection from the presumably un-favourable conditions existing throughout the winter months. This migration only occurs when the atmosphere has a temperature of at least 6° C. and a saturation deficiency of not more than 6 mm. of mercury during several hours of daylight, since the insect has never been observed to migrate in darkness either in the laboratory or in the field. The wind velocity must also be low for migration to occur.

In the spring the gradual rise in the mean daily temperature apparently leads to a loss of coldhardiness to some extent, breaking up of the overwintering clusters, and, possibly, a migration to fresh host-plants; this migration requiring similar environmental conditions to those necessary for the autumn migration. Probably the rise in temperature also leads to the commencement of oviposition for the year, which generally takes place about May. Temperature also plays an important part in determining the rate and extent of oviposition, the length of the life-cycle, and, consequently, the number and size of generations of *A. brassicae* throughout the year.

Wind velocity also plays some part in determining the number of *A. brassicae* in the field and the number of eggs laid. In the early summer, after the spring migration, when oviposition commences, a high wind velocity causes large numbers of female Whiteflies to be blown from their host-plants and perish. Consequently these females fail to lay their full quota of eggs. Even when the wind is not sufficiently strong to separate *A. brassicae* from its host-plant, it probably delays and interferes with oviposition. Thus in June 1935 many egg patches were found containing only one or two eggs instead of the usual ten or twenty, no female being present.

The velocity of the wind can also have an appreciable effect upon the numbers of *A. brassicae* present in the field in June or at any future time in the year, by tearing off the leaves of the host-plant bearing any of the life-history stages. Most of these stages, with the possible exception of the pupae and adults, perish once the leaf on which they are living is detached from the host-plant and withers.

The physical factors of the environment usually classed together as "weather" also exert a very great influence over the growth and well-being of the host-plants of *A. brassicae*, which naturally reflects on the Whitefly itself in all its stages. Thus high temperature combined with low rainfall leads to some degree of desiccation of the host-plant and this in turn may lead, other factors becoming favourable, to migration of the Whiteflies to fresh plants. Heavy rainfall in the early summer, combined with moderate or high temperature, as in 1935, frequently causes the host-plants to grow large fleshy leaves. This tends to cause increased space between the egg patches of *A. brassicae*, and hence between the groups of nymphs. In consequence a lower degree of parasitic or predatory control is likely to be evidenced, since the parasite or predator has to expend more energy in finding its host than if the groups of nymphs arising from separate egg patches were nearer to one another. (This has been observed experimentally in the laboratory.)

Wide spacing of the individual groups of nymphs probably leads to wide spacing of the adults, consequently there is less chance of copulation occurring and therefore a great production of males from unfertilised eggs, with a consequent reduction in the size of future generations.

The physical factors of the environment may also have a differential effect on the predators and parasites of *A. brassicae* and *A. brassicae* itself. Thus a late frost at the end of May, when both the parasite and *A. brassicae* may be considered to have lost what coldhardiness they possessed, may kill off more parasites than Whiteflies, since the latter can at all times withstand a much lower temperature than the parasite.

Again, the physical factors of the environment may have a differential effect on the Whiteflies and on their host-plants. High temperature and low rainfall in the spring will tend to cause stunting and slow growth of the host-plants whereas, unless actual desiccation of the host-plant occurs, the temperature alone affects *A. brassicae* living in its micro-environment on the leaf surface, and an increased rate of development will be caused. This may lead to overcrowding of the small amount of available leaf surface with consequent higher mortality among the larvae, the adults frequently being caused to migrate by the overcrowding.

Biological factors which have a profound effect on the number of Whiteflies in the field are the number of parasites and predators present; the number of host-plants attacked and destroyed by the Cabbage Root-Fly, *Hylemyia brassicae* Bché., the Flea beetle, *Phyllotreta* sp., the Cabbage Aphis, *Brevicoryne brassicae* Linn., or one or more of the Lepidoptera attacking *A. brassicae.*

A fairly good theoretical estimate of the number of *A. brassicae* in the field at a given time may thus be obtained provided that an accurate estimate of the number of Whiteflies present at a previous date, and measurements of the factors of the environment from that date, are known.

7. *Summary.*

(*a*) Various parasites and predators attacking *A. brassicae* are discussed, the most important being two Chalcid parasites of the later larval stages, *Encarsia partenopea* Masi., and *E. tricolor* Förster. The latter being a species new to this country. Both are probably of Italian origin, and although they lay a large number of parthenogenetic eggs and their life-cycle is very rapid under favourable conditions, they are of little actual use in controlling the numbers of *A. brassicae*, since they do not seem to be able to withstand the winter in this country.

(*b*) Experiments on the effect of high temperature on *A. brassicae* adults showed that the optimum temperature for life was below 30° C., but that 22% of the adults used in an experiment could withstand a temperature of 37° C. for five days.

(*c*) Experiments on the coldhardiness of eggs, pupae and adults of *A. brassicae*, both in the autumn and spring, showed that low temperature causes a heavy mortality among the eggs of *A. brassicae*, but even when the temperature was as low as — 15° C., in the autumn, the vast majority of the pupae and adults survived. In the spring and early summer, however, a large proportion of their coldhardiness has been lost and only about 50% of the pupae and adults survive when subjected to low temperatures. It was also shown that unmated males can survive much greater cold than males that have paired.

(*d*) Experiments were also conducted to determine the effect of different temperatures at a constant saturation deficiency on the rate of oviposition. It was found that, within the limits of experimental error, there is a direct relationship between temperature and the number of eggs laid in a given time.

(*e*) Experiments were conducted at a constant temperature of 18° C. to determine the effect of different saturation deficiencies on the rate of oviposition of *A. brassicae.* Various very different saturation deficiencies were used but only very small fluctuations in the number of eggs laid were noted. This is thought to be due to the fact that the insect is living in a micro-environment on the leaf surface in which the temperature is probably much the same as that of the external environment, but in which the humidity is very much higher owing to the continual loss of water vapour by transpiration from the leaf. That this theory is probably correct has been shown in a previous paper (Ramsay, Butler and Sang 1938).

(*f*) The causes of migration of *A. brassicae* are discussed. It was found that any factor causing wilting of the host-plant causes migration, as does overcrowding of the adults; but by far the most important cause is temperature. Low temperature in the autumn causes migration to places of shelter on the host-plants, and the rise in the mean daily temperature in the spring causes migration to fresh host plants. For migration to take place successfully the temperature of the atmosphere must be over 6° C. and the saturation deficiency less than 6 mm. of mercury.

(*g*) The extent to which the biotic and physical factors of the environment affect *A. brassicae* in nature is discussed. It is concluded that a fairly good theoretical estimate of the numbers of *A. brassicae* in the field at a given time may be obtained from a previous study of the biotic and physical factors of the environment.

8. *References.*

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BOOK NOTICE.

Zoo-parasitos de Interesse Medico e Veterinario. By CESAR PINTO. pp. [viii] + vii + 376 + [i], 105 pls. + 8 portraits + 1 pl. col. + 1 table, 162 figs. 4to. Rio de Janeiro (Pimenta de Mello & Cia.) 1938.

This text book is addressed to those interested in Medicine, Hygiene or Veterinary Medicine, of the Neotropical region, especially of Brazil.

It is divided in three parts as follows. Chapters 1–4 Protozoology, Chapters 5–23 Entomology, Chapters 24–34 Helminthology.

In Part 2 Entomology is understood to include mites and ticks, the true insects being described on pp. 82–172.

After a general description of the orders dealt with, keys are given to the families and genera, followed by tables giving hosts and such additional information as may be useful.

In the case of large or complicated genera, keys are given to the species, and many figures are supplied throughout the text and on the plates. Many illustrations of the effects of parasitism are given, and life-cycles of parasites are illustrated in detail.

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